HYSPLIT Nuclear Applications and Emergence Response

Presenter: **Tianfeng Chai**

Other Team Members: **Alice Crawford, Hyun-Cheol Kim, Mark Cohen**

NOAA Air Resources Laboratory

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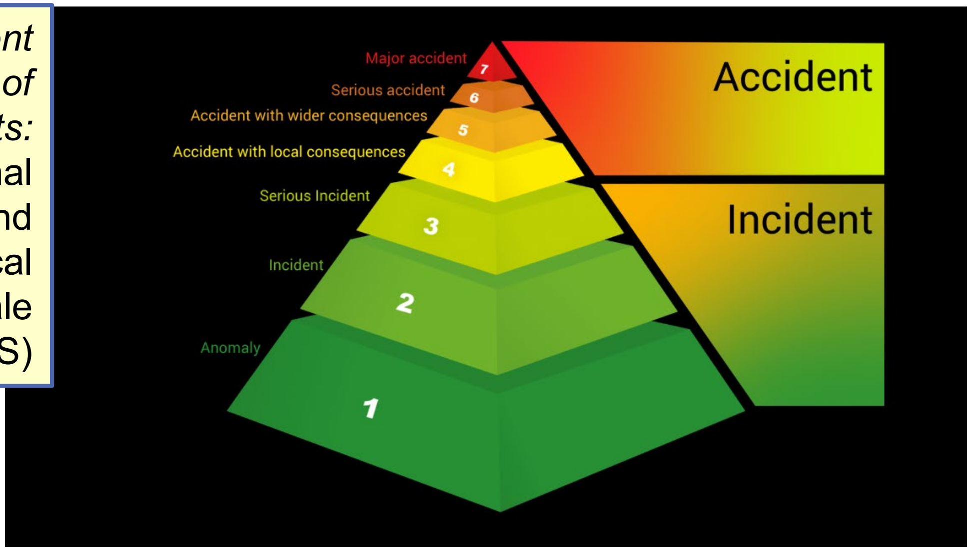
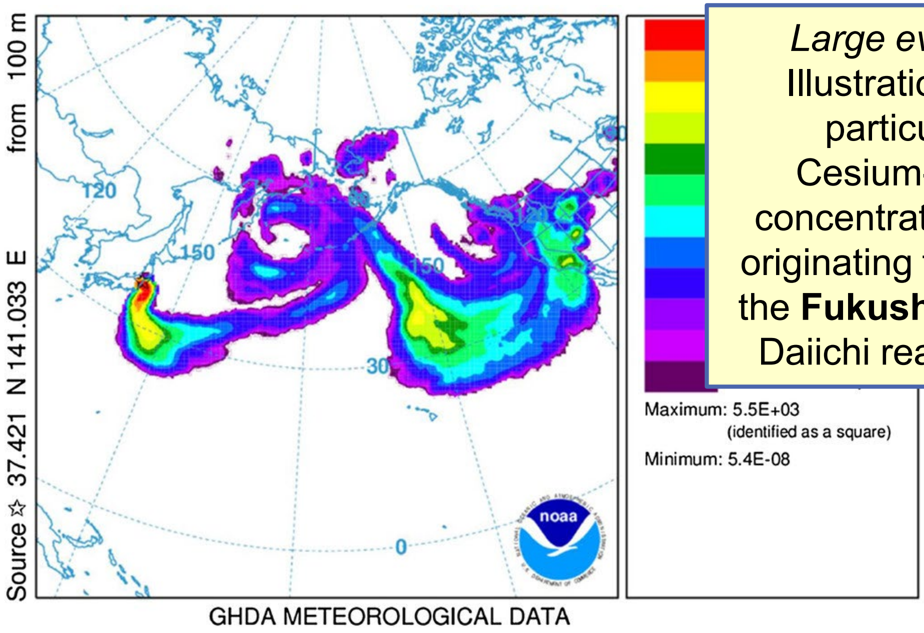
HYSPLIT Nuclear Applications and Emergence Response

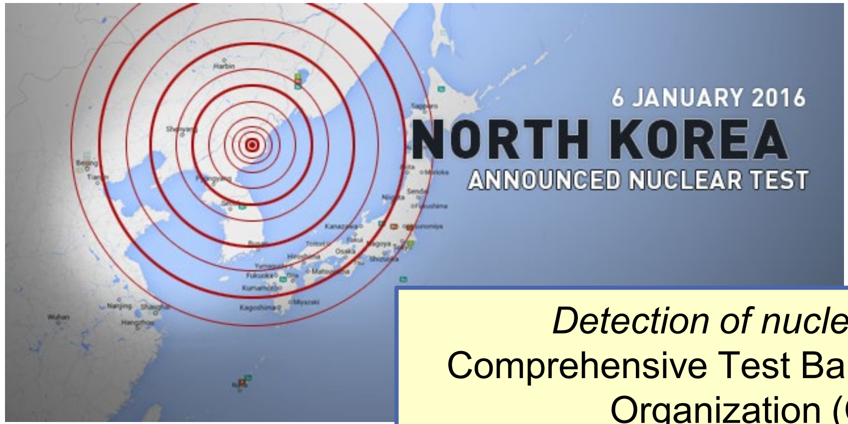
Different Types of events: International Nuclear and Radiological Event Scale (INES)



Large event: Illustration of particulate Cesium-137 concentrations originating from the **Fukushima** Daiichi reactor



Small event: The NIST Center for Neutron Research had elevated radiation levels on Feb 3, 2021

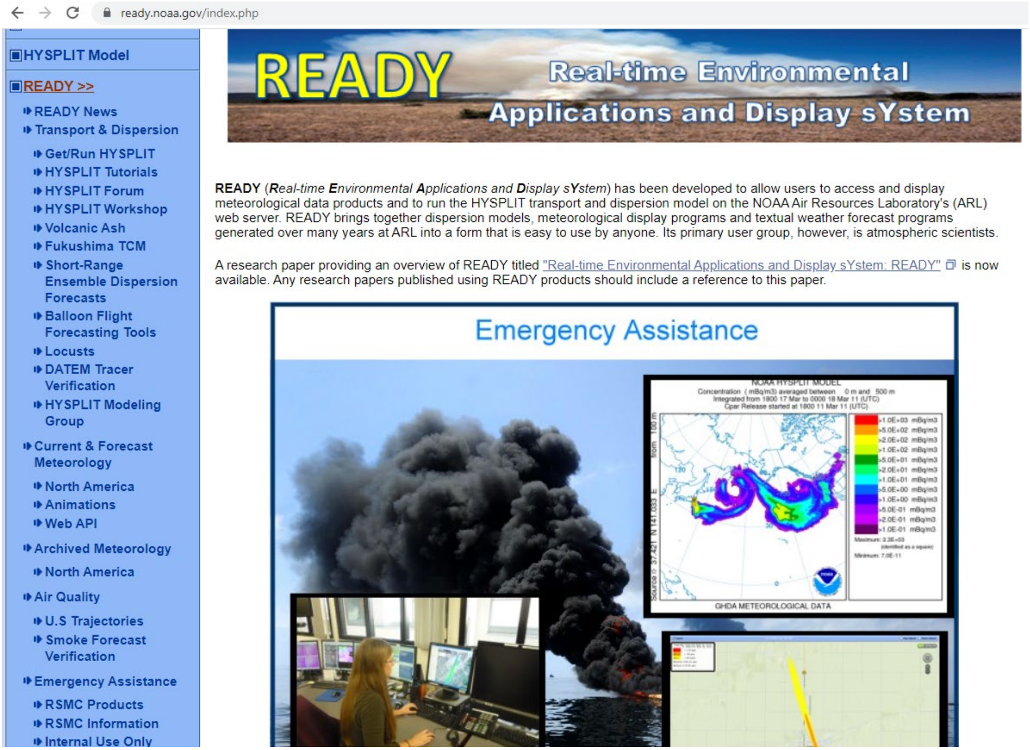


Detection of nuclear tests: Comprehensive Test Ban Treaty Organization (CTBTO)

Relevance to NOAA mission

Make forecasts better

Improving HYSPLIT models, meteorological inputs, and emissions

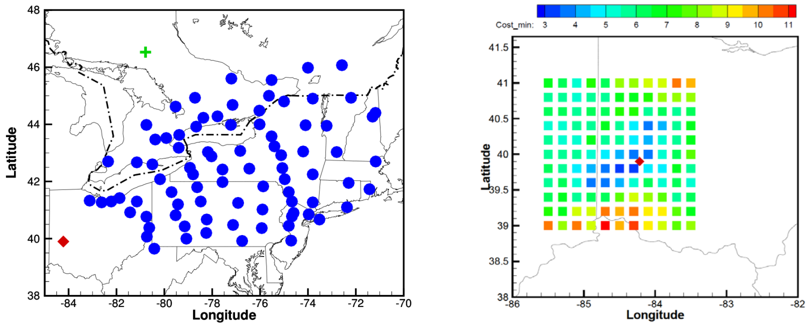


Share knowledge and information with others

Working with many other int'l & national agencies / organizations for nuclear emergency preparedness and response

Drive Innovative Science

Developing Transfer Coefficient Matrix (TCM) approach, and exploring various inverse modeling techniques to utilize measurements to estimate unknown emissions

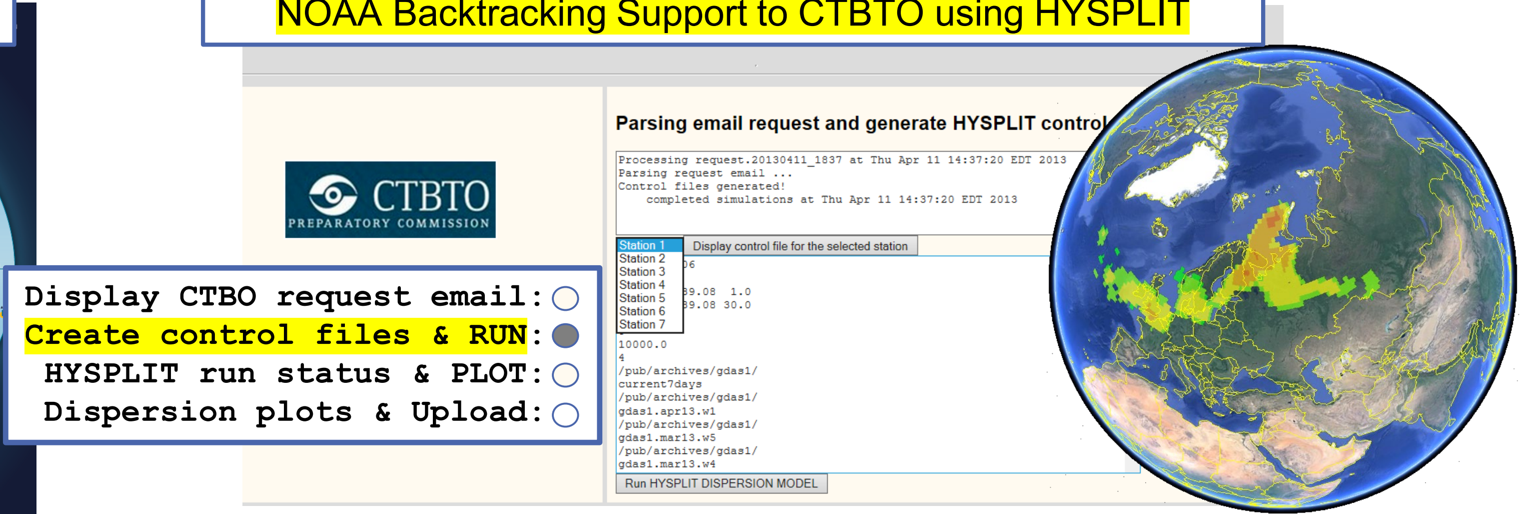


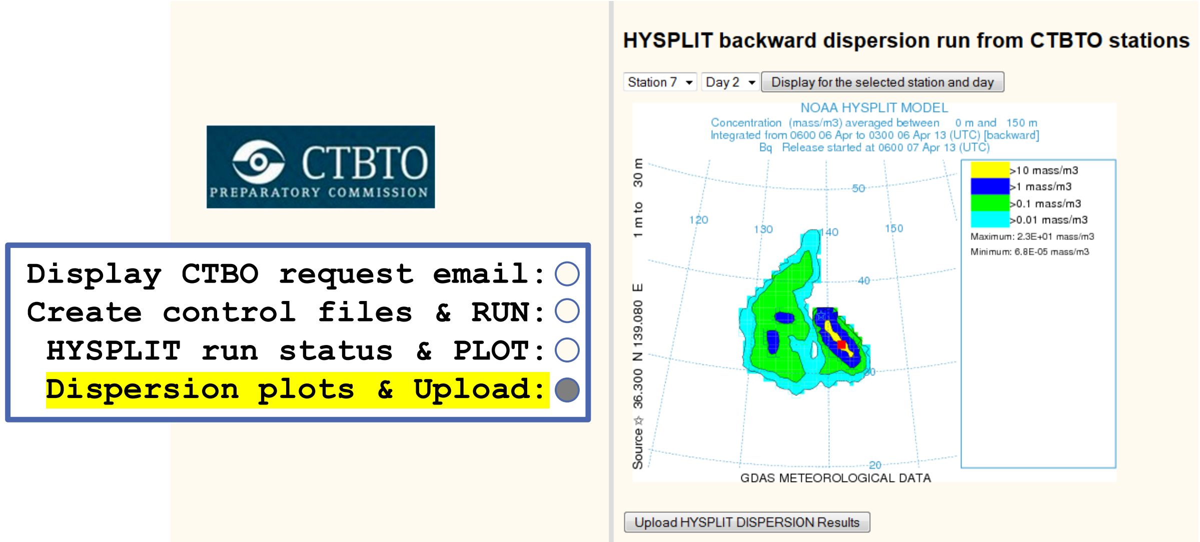
Chai et al., 2018

NOAA Backtracking support to Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) using HYSPLIT (On-demand Operation)

CTBTO International Monitoring System

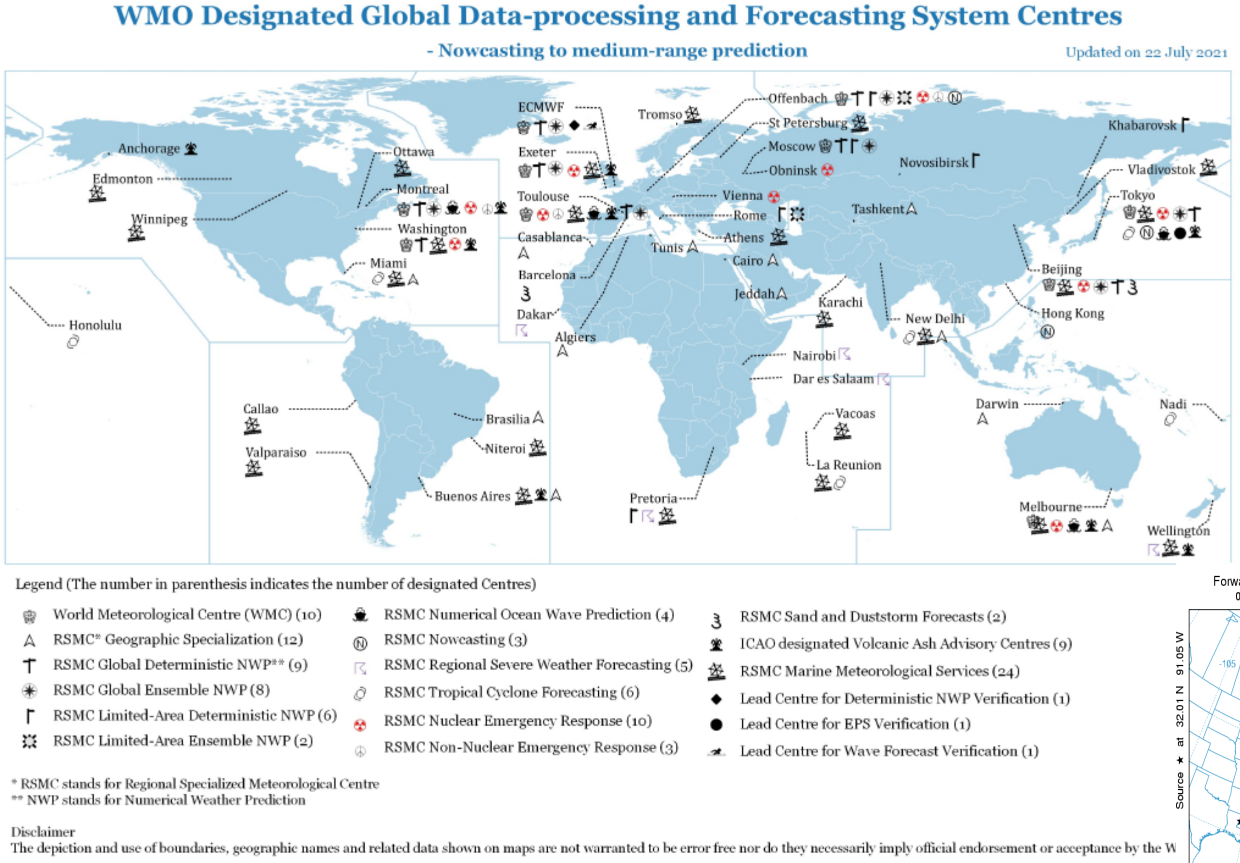
NOAA Backtracking Support to CTBTO using HYSPLIT





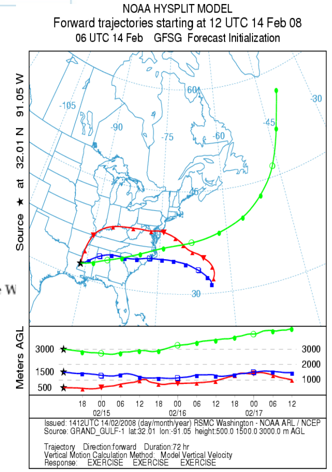
- ARL developed HYSPLIT-based software for on-demand provision of backtracking support to CTBTO
- Operational at NOAA/NCEP since 2014.
- CTBTO sends a request when one or more of its 80 radionuclide stations detect high air concentrations.
- Backward dispersion results are sent back to CTBTO for source term estimation (location and strength).
- ARL has continuously provided support and updates to this on-demand operation.

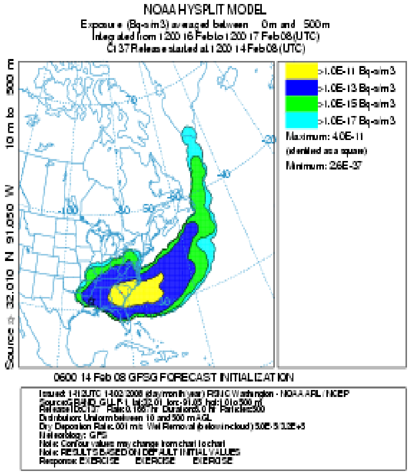
WMO's RSMC Emergency Response Activities (ERA)

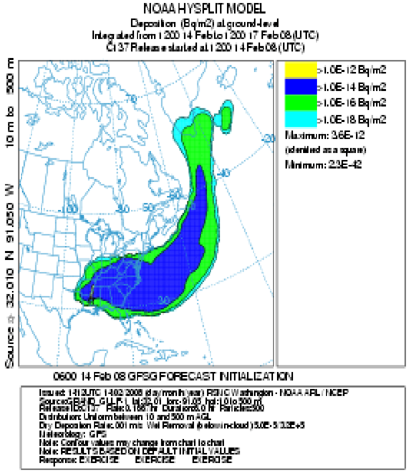


There are a total of 10 Regional Specialized Meteorological Centres (RSMCs) designated by WMO for Nuclear Emergency Response.

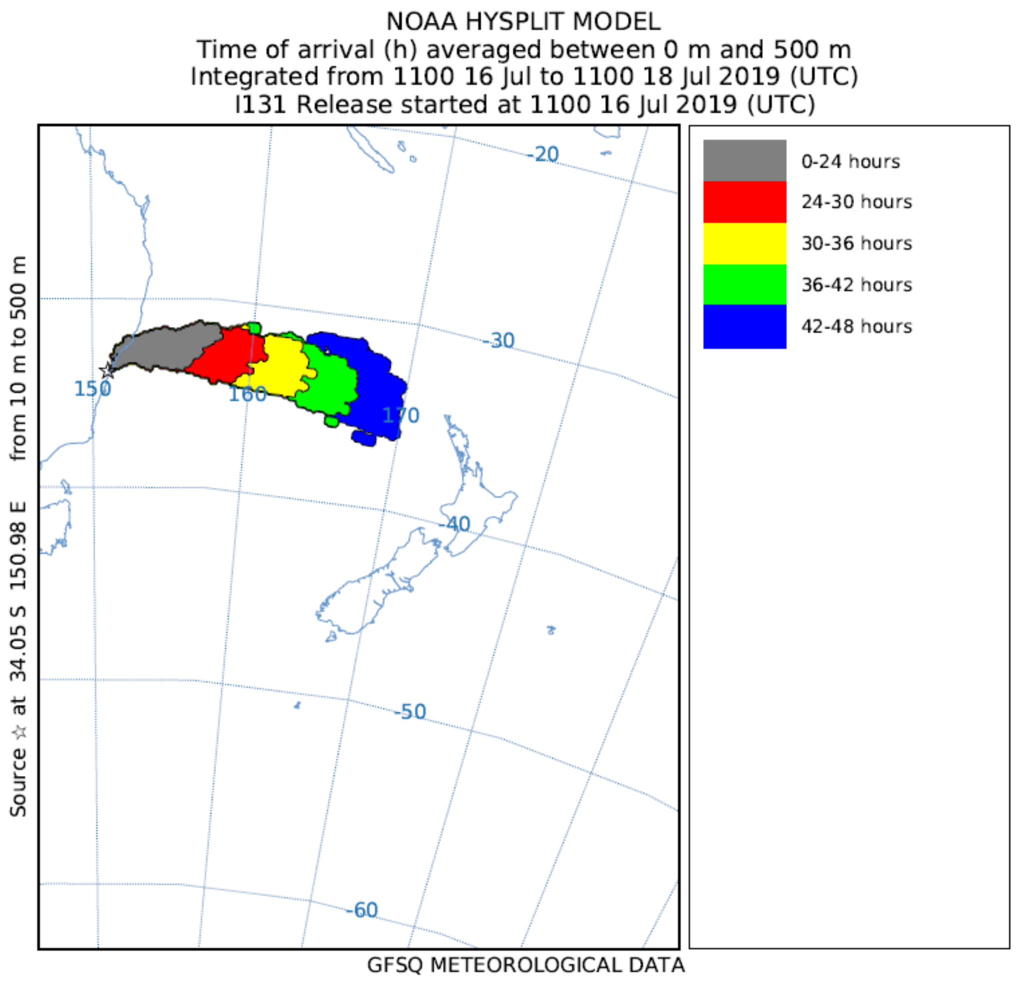
- ARL, together with NOAA NWS NCEP, are designated by the WMO as the Washington Regional Specialized Meteorological Centre (RSMC), one of ten worldwide RSMCs for emergency environmental response related to potential radionuclide sources.
- Beginning in 1993 and formalized in 2007, ARL has been performing routine monthly forecast exercises with other RSMC partners and the International Atomic Energy Agency (IAEA), including transferring forecasting results to and from all the other centers.







Time of Arrival (ToA) and Transfer Coefficient Matrix (TCM) Products

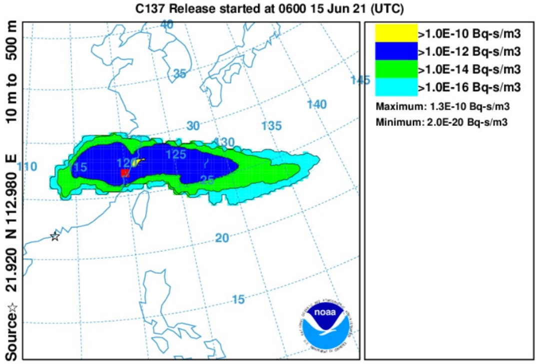


- ToA (Expected to be operational in 2022)
  - The code to calculate the pollutant Time of Arrival and a Python program for plotting ToAs have been developed.
- TCM (under development)
  - The simulation is divided into smaller time segments and each segment is an independent calculation using a unit source emission.
  - The set of calculations for all emission times is defined as the Transfer Coefficient Matrix (TCM).
  - When quantitative results are required, the actual air concentrations and depositions are computed in a simple post-processing step by multiplying the TCM by the appropriate time-varying emission rates and radioactive decay constant for each relevant radionuclide.
  - Allows updated forecasts to be quickly produced when new emissions estimates are made available

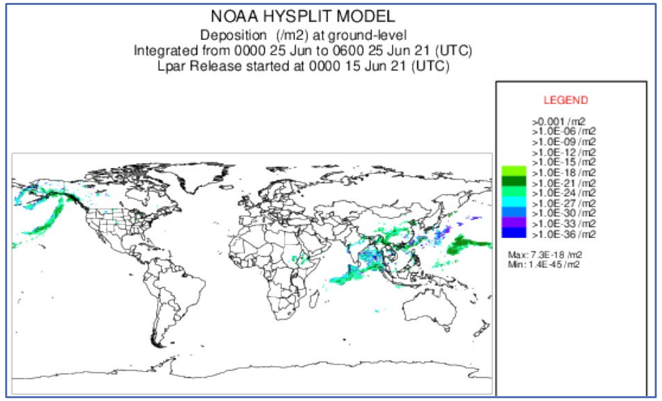
Implement Transfer Coefficient Matrix (TCM) Approach in Radionuclide Transport and Dispersion Forecasting – Ongoing

- A total of 20 6-hr releases with unit emissions from Taishan NPP were run through June 27, 2021.
- Four surrogates (Hpar, Lpar, Dgas, Ngas) used.
- Decay and dose calculated in post-processing
- Maps at right are based on unit emissions
- Could be used to estimate actual impacts by multiplying actual estimated emissions

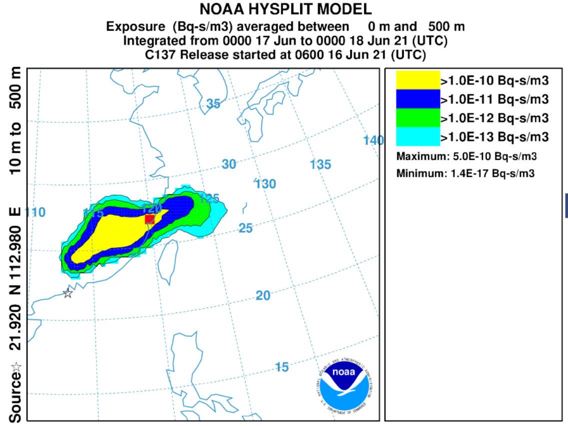
Estimated exposure Jun 17, based on 6-hr unit emission release 0-6Z June 15



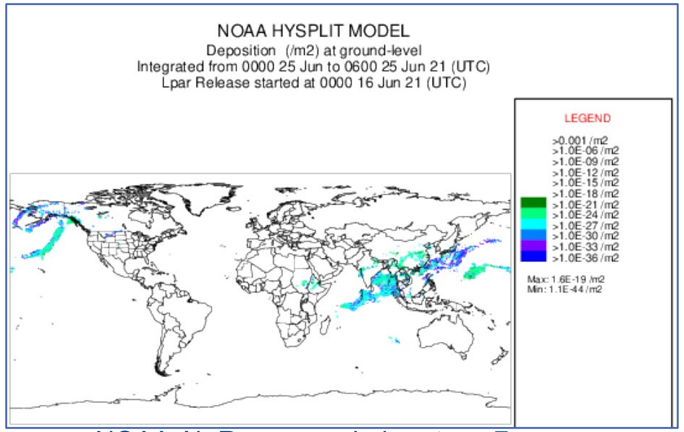
Estimated deposition Jun 25 based on 6-hr unit emission release 0-6Z June 15



Estimated exposure Jun 17, based on 6-hr unit emission release 0-6Z June 16

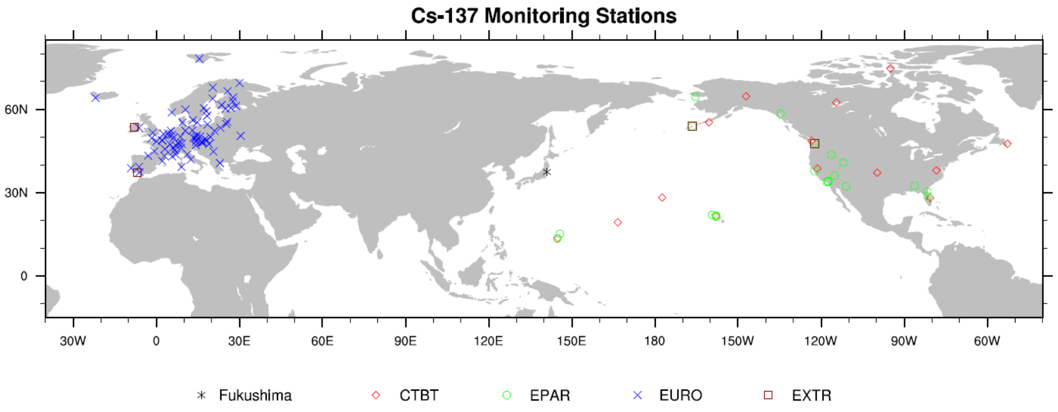


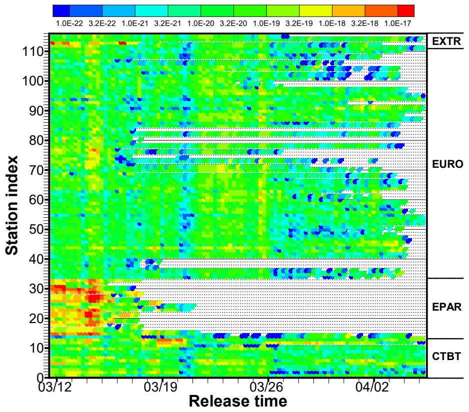
Estimated deposition Jun 25 based on 6-hr unit emission release 0-6Z June 16

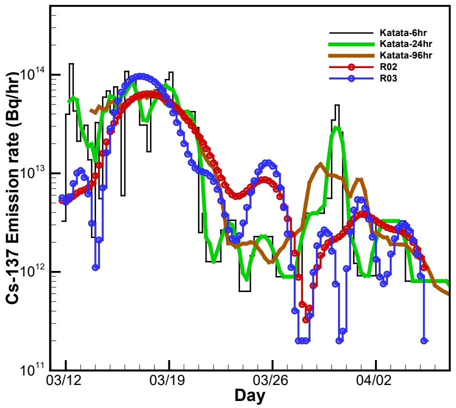


Inverse Modeling – From research to future operation

Fukushima accident: Cs-137 Source term estimation using air concentration measurements



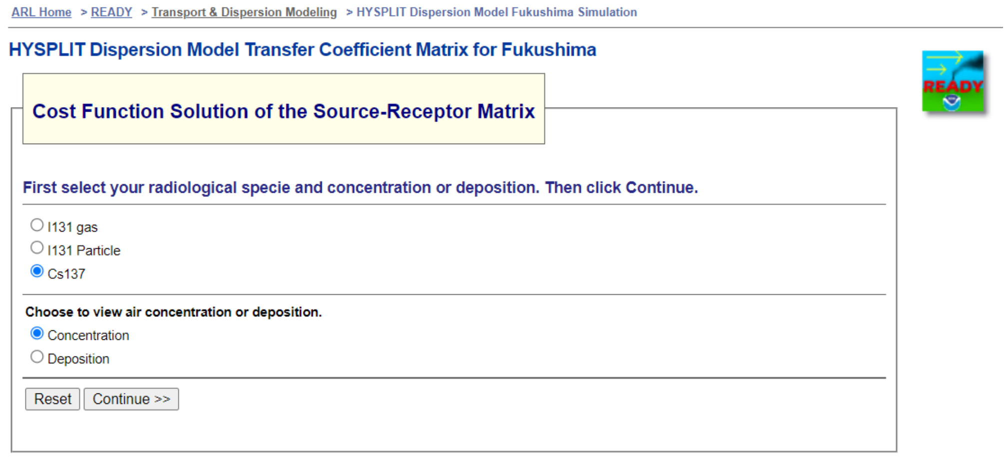




Source term estimation using air concentration measurements and a Lagrangian dispersion model–Experiments with pseudo and real cesium-137,
T Chai, R Draxler, A Stein – *Atmos. Environ.*, 2015

Working with EPA, a web application has been developed.

https://www.ready.noaa.gov/fdnppepa-noaa/setsrcfuka.pl
(Restricted access to NOAA users and registered HYSPLIT users only)



ARL Home > READY > Transport & Dispersion Modeling > HYSPLIT Dispersion Model Fukushima Simulation

HYSPLIT Dispersion Model Transfer Coefficient Matrix for Fukushima

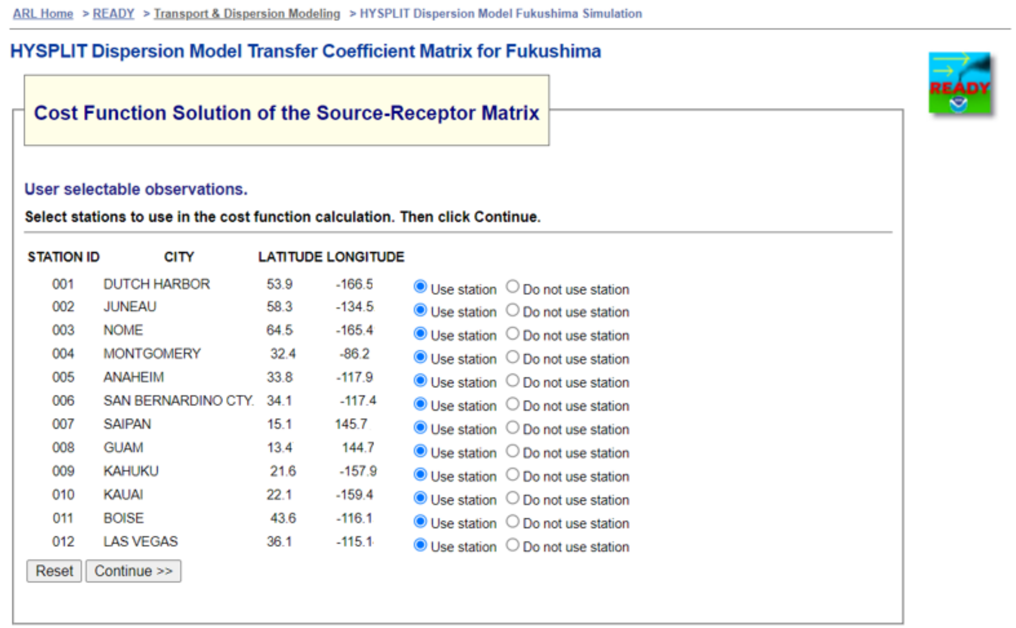
Cost Function Solution of the Source-Receptor Matrix

First select your radiological specie and concentration or deposition. Then click Continue.

I131 gas
I131 Particle
Cs137

Choose to view air concentration or deposition.
Concentration
Deposition

Reset Continue >>



ARL Home > READY > Transport & Dispersion Modeling > HYSPLIT Dispersion Model Fukushima Simulation

HYSPLIT Dispersion Model Transfer Coefficient Matrix for Fukushima

Cost Function Solution of the Source-Receptor Matrix

User selectable observations.

Select stations to use in the cost function calculation. Then click Continue.

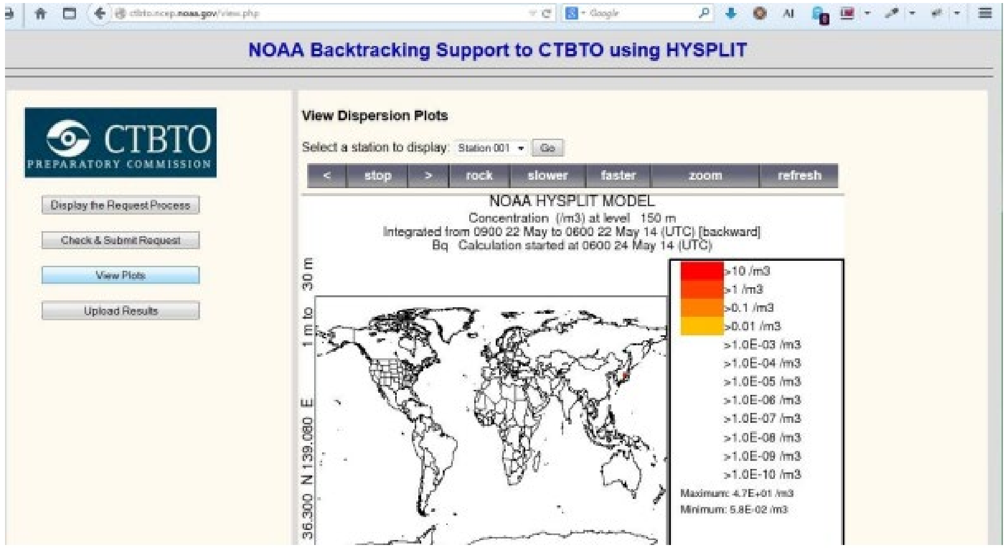
STATION ID	CITY	LATITUDE	LONGITUDE		
001	DUTCH HARBOR	53.9	-166.5	Use station	Do not use station
002	JUNEAU	58.3	-134.5	Use station	Do not use station
003	NOME	64.5	-165.4	Use station	Do not use station
004	MONTGOMERY	32.4	-86.2	Use station	Do not use station
005	ANAHEIM	33.8	-117.9	Use station	Do not use station
006	SAN BERNARDINO CTY.	34.1	-117.4	Use station	Do not use station
007	SAIPAN	15.1	145.7	Use station	Do not use station
008	GUAM	13.4	144.7	Use station	Do not use station
009	KAHUKU	21.6	-157.9	Use station	Do not use station
010	KAUAI	22.1	-159.4	Use station	Do not use station
011	BOISE	43.6	-116.1	Use station	Do not use station
012	LAS VEGAS	36.1	-115.1	Use station	Do not use station

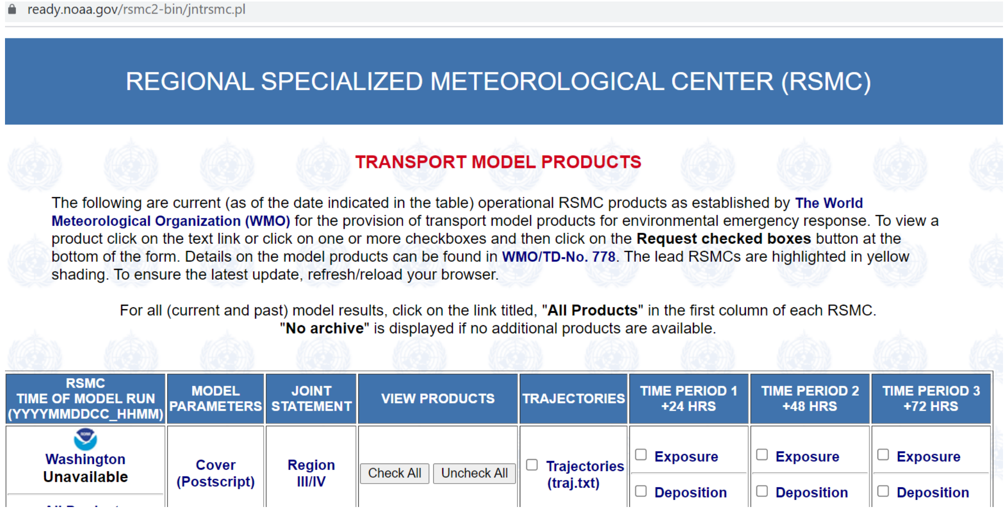
Reset Continue >>

Quality and Performance: *Operational Implementations*

- The CTBTO on-demand operations was transitioned from ARL to NCEP for operation in September 2014. ARL has provided several updates to the system for the continuous operation (with ~10 requests each year).

- ARL has continued the WMO RSMC monthly exercises with the assistance of NCEP Operation Center (NCO) since its formal operation in 2007 to present. ARL is also assisting NCEP/NCO to build its website at NCO to replace the current ARL website. Time of Arrival (ToA) and TCM products are being developed.




ready.noaa.gov/rsmc2-bin/jntrsmc.pl

REGIONAL SPECIALIZED METEOROLOGICAL CENTER (RSMC)

TRANSPORT MODEL PRODUCTS

The following are current (as of the date indicated in the table) operational RSMC products as established by The World Meteorological Organization (WMO) for the provision of transport model products for environmental emergency response. To view a product click on the text link or click on one or more checkboxes and then click on the **Request checked boxes** button at the bottom of the form. Details on the model products can be found in WMO/TD-No. 778. The lead RSMCs are highlighted in yellow shading. To ensure the latest update, refresh/reload your browser.

For all (current and past) model results, click on the link titled, "**All Products**" in the first column of each RSMC. "**No archive**" is displayed if no additional products are available.

RSMC TIME OF MODEL RUN (YYYYMMDDCC_HHMM)	MODEL PARAMETERS	JOINT STATEMENT	VIEW PRODUCTS	TRAJECTORIES	TIME PERIOD 1 +24 HRS	TIME PERIOD 2 +48 HRS	TIME PERIOD 3 +72 HRS
Washington Unavailable	Cover (Postscript)	Region III/IV	Check All / Uncheck All	☐ Trajectories (traj.txt)	☐ Exposure ☐ Deposition	☐ Exposure ☐ Deposition	☐ Exposure ☐ Deposition

Quality and Performance: *Publications*

Maurer C., J. Baré, J. Kusmierczyk-Michulec, **A. Crawford**, P.W. Eslinger, Pe. Seibert, B. Orr, A. Philipp, O. Ross, S. Generoso, P. Achim, M. Schoeppner, A. Malo, A. Ringbom, O. Saunier, D. Quèlo, A. Mathieu, Y. Kijima, **A. Stein, T. Chai, F. Ngan,** S. J Leadbetter, P. De Meutter, A. Delcloo, R. Britton, A. Davies, L.G. Glascoe, D.D. Lucas, M. D Simpson, P. Vogt, M. Kalinowski, T.W. Bowyer (2018). International challenge to model the long-range transport of radioxenon released from medical isotope production to six Comprehensive Nuclear-Test-Ban Treaty monitoring stations, *J. of Environ. Radioactivity***,** 192**,** pp. 667-686, doi:10.1016/j.jenvrad.2018.01.030.

P.W. Eslinger, T. W Bowyer, P.Achim, **T. Chai**, B. Deconninck, K. Freeman, S. Generoso, P. Hayes, V. Heidmann, I. Hoffman, Y. Kijima, M. Krysta, A. Malo, C. Maurer, **F. Ngan**, P. Robins, J.O. Ross, O. Saunier, C. Schlosser, M. Schöppner, B. T Schrom, P. Seibert, **A. Stein**, K. Ungar, J. Yi (2016). International challenge to predict the impact of radioxenon releases from medical isotope production on a comprehensive nuclear test ban treaty sampling station, *J. Environ. Radioactivity,* 157, pp 41-51, doi:10.1016/j.jenvrad.2016.03.001.

Quality and Performance: *Presentations*

- Cohen, M., T. Chai, A. Crawford, H. Kim, C. Loughner, T. McKinney, F. Ngan, A. Ring, and S. Zinn, “The NOAA HYSPLIT Atmospheric Transport and Dispersion Model: Recent Updates and Nuclear Applications”, 2021 International MACCS Users Group (IMUG) Meeting, Sept 20-22, 2021.
- Chai, T., “NOAA' experience in source inversion and radioactivity emergency response problems”, IAEA (International Atomic Energy Agency) Meeting on Sharing Experience in Source Term Estimation and Air Dispersion Modelling for Nuclear Emergency Preparedness and Response, virtual meeting hosted in Beijing, China, July 5-7, 2021.
- Chai, T., “NOAA' experience in the use of HYSPLIT in inverse modelling (with demo)”, IAEA (International Atomic Energy Agency) Meeting on Sharing Experience in Source Term Estimation and Air Dispersion Modelling for Nuclear Emergency Preparedness and Response, virtual meeting hosted in Beijing, China, July 5-7, 2021.
- Chai, T, F. Ngan, and A. Stein, “HYSPLIT Inverse Modeling”, 2019 International MACCS Users Group (IMUG) Meeting, June 10-11, 2019.
- Chai, T, A. Stein, H. Kim, F. Ngan, A. Crawford, B. Stunder, M.J. Pavolonis, and S. Kondragunta, “HYSPLIT Inverse Modeling”, 20th George Mason University Conference on Atmospheric Transport and Dispersion Modeling, Fairfax, VA, USA, June 18-20, 2019.
- Chai, T, F. Ngan, and A. Stein, “Data assimilation and inverse modeling with HYSPLIT Lagrangian dispersion model”, Seventh International WMO Symposium on Data assimilation, Florianópolis, Brazil, Sept 11-15, 2017.
- Stein, A., R.R. Draxler, G.D. Rolph, B. Stunder, M. Cohen, and F. Ngan, “NOAA’s HYSPLIT atmospheric transport and dispersion modeling system: history, applications, and new developments”, 2016 International MACCS Users Group (IMUG) Meeting, Sept 2016.

Future Plans

CTBTO On-demand Operation and RSMC Emergency Response activities

- Continue to support NCEP/NCO for CTBTO and RSMC operations;
- Implement HYSPLIT updates;
- Port to WCOSS2, the new operational and R&D high performance computing system;
- Implementation of TCM approach for the RSMC products;
- Assist other RSMCs to implement the TCM approach;
- Pending NCEP/NCO decision, convert CTBTO operations from NCO intranet to WCOSS application.

Research and development

- Continue to develop and improve the HYSPLIT-based inverse system for source term estimation
- Revisit the Fukushima accident case for inverse modeling using near-source measurements
- Work with US EPA to continue the development of source term estimation website
- Continue participating in model intercomparisons of the long-range transport of radionuclides, including the ongoing “Radioxenon Nuclear Explosion Signal Screening Inter-Comparison Exercise 2021”
- Test ensemble runs to quantify the uncertainties in HYSPLIT dispersion results
- Include uncertainties to the source term estimation results
- Explore machine-learning techniques for better source term estimation